

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**FEE TRANSMITTAL****for FY 2000**

Patent fees are subject to annual revision.

Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12.

See 37 C.F.R. §§ 1.27 and 1.28.

TOTAL AMOUNT OF PAYMENT (\$)**710.**

Complete if Known

Application Number	
Filing Date	on even date
First Named Inventor	Dawes
Examiner Name	
Group / Art Unit	
Attorney Docket No.	551P08US-1

JC925 U.S. PTO  
09/678783

10/04/00

**METHOD OF PAYMENT (check one)**

- 1.
- ☐
- The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number **16-0600**Deposit Account Name **Pascal & Associates**☒ Charge Any Additional Fee Required Under 37 CFR §§ 1.16 and 1.17

- 2.
- ☒
- Payment Enclosed:

☒ Check ☐ Money Order ☐ Other**FEE CALCULATION****1. BASIC FILING FEE**

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
101 690	201 345	Utility filing fee	<b>710.</b>
106 310	206 155	Design filing fee	
107 480	207 240	Plant filing fee	
108 690	208 345	Reissue filing fee	
114 150	214 75	Provisional filing fee	

SUBTOTAL (1) (\$)**710.****2. EXTRA CLAIM FEES**

Total Claims	Extra Claims	Fee from below	Fee Paid
<b>16</b>	-20** =	X	
Independent Claims <b>3</b>	-3** =	X	
Multiple Dependent			

\*\*or number previously paid, if greater; For Reissues, see below

**Large Entity Small Entity**

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description
103 18	203 9	Claims in excess of 20
102 78	202 39	Independent claims in excess of 3
104 260	204 130	Multiple dependent claim, if not paid
109 78	209 39	** Reissue independent claims over original patent
110 18	210 9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$)

**FEE CALCULATION (continued)****3. ADDITIONAL FEES**

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
105 130	205 65	Surcharge - late filing fee or oath	
127 50	227 25	Surcharge - late provisional filing fee or cover sheet	
139 130	139 130	Non-English specification	
147 2,520	147 2,520	For filing a request for reexamination	
112 920*	112 920*	Requesting publication of SIR prior to Examiner action	
113 1,840*	113 1,840*	Requesting publication of SIR after Examiner action	
115 110	215 55	Extension for reply within first month	
116 380	216 190	Extension for reply within second month	
117 870	217 435	Extension for reply within third month	
118 1,360	218 680	Extension for reply within fourth month	
128 1,850	228 925	Extension for reply within fifth month	
119 300	219 150	Notice of Appeal	
120 300	220 150	Filing a brief in support of an appeal	
121 260	221 130	Request for oral hearing	
138 1,510	138 1,510	Petition to institute a public use proceeding	
140 110	240 55	Petition to revive - unavoidable	
141 1,210	241 605	Petition to revive - unintentional	
142 1,210	242 605	Utility issue fee (or reissue)	
143 430	243 215	Design issue fee	
144 580	244 290	Plant issue fee	
122 130	122 130	Petitions to the Commissioner	
123 50	123 50	Petitions related to provisional applications	
126 240	126 240	Submission of Information Disclosure Stmt	
581 40	581 40	Recording each patent assignment per property (times number of properties)	
146 690	246 345	Filing a submission after final rejection (37 CFR § 1.129(a))	
149 690	249 345	For each additional invention to be examined (37 CFR § 1.129(b))	

Other fee (specify) \_\_\_\_\_

Other fee (specify) \_\_\_\_\_

\* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$)

**SUBMITTED BY**Name (Print/Type) **Harold C. Baker**

Registration No. (Attorney/Agent)

**19333**

Complete (if applicable)

Telephone **613 820-1366**

Signature

Date **Oct. 3, 2000****WARNING:**

Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

METHOD OF DETERMINING THE ROUTE OF PACKETS THROUGH A  
NETWORK OF COMMUNICATING OBJECTS

Field of the Invention

5           The present invention relates to computer networks and, more specifically, to methods which determine the route of packets through a network.

Background to the Invention

10           Operators of communications networks often need to know the path that packets take between two points in a network. As an example, if an end user complains that he cannot get through to a particular server, the operator of that network needs to find out  
15           where the problem may be. If the problem is with a point on the network, the operator therefore needs to find the route packets from the end user travel toward the server in the network to properly diagnose the problem.

20           Two scenarios where the routing of packets can be quite useful are in determining the performance of a network and in determining where the bottlenecks of a network may be. In the first scenario, the performance of specific routes can be determined if the  
25           routing can be found. In the second scenario, by listing each point in the route bottlenecks in the network can be found. However, while the solution and results can be found for both scenarios using other means, knowledge of the routes greatly simplifies the  
30           process.

          It should be noted that the term networks

includes wide area networks (WANs), local area networks (LANs), and many combinations thereof. For the purposes of this document, WANs are defined as collections of interconnected network routers bounded by LANs. A LAN is defined as a collection of interconnected non-router objects (including nodes, servers, and bridges), each LAN being connected to other LANs by routers.

For any given network, it is most advantageous if the topology of that network is known. Such knowledge would assist in the above routing determination problem. Fortunately, methods, such as those disclosed by Dawes et al in US Patent 5,926,462 and US Patent 5,933,416, exist whereby the topology of a network of objects can be determined the disclosures of which are incorporated by reference.

From the above, there is therefore a need for methods to determine the route that a packet takes through a network. Preferably, such methods would take advantage of available processes such as those referenced above.

#### Summary of the Invention

The present invention meets the above need by providing methods which decompose a network into WAN and LAN segments. After the decomposition, the route is determined for each WAN and LAN segment. Often, the WAN path is unambiguously known from the topology of the network. For WAN segments where the path is ambiguous, the sequence of routers in the path from a source to a destination can be determined by the standard "traceroute" method. This allows for the aggregation of multiple path sections to arrive at the full packet path through the WAN segment. For most LAN segments, the

path is unambiguously known from the topology. In LAN segments where the path is ambiguous, perhaps because of VLANs (Virtual LANs), every store and forward network element in the LAN segment tracks and can report the source addresses of packets which pass through it. By reading these records and noting which network element received a packet from a specific source address, the route of that packet can be mapped through that LAN segment.

By combining the mapped path through multiple LAN segments with the full packet path through the different WAN segments, the full route a packet traverses through a network can be determined.

Using the invention, not only can the packet routing through a network be found but the performance of specific portions of the network can be found as well. This can simplify the task faced by network operators and, ultimately, can improve the service provided to end users using the network.

In one aspect the present invention provides a method of determining a routing for packets in a network, said method comprising:

- a) dividing said network into WAN (Wide Area Network) segments and LAN (Local Area Network) segments;
- b) determining a routing for packets through each segment;
- c) combining routing results obtained in step b) to obtain a total routing through the network.

#### Brief Description of the Drawings

A better understanding of the invention may be obtained by reading the detailed description of the invention below, in conjunction with the following

drawings, in which:

Figure 1 illustrates a network on which the invention may be applied;

Figure 2 is an illustration of a network of Figure 1 decomposed into LAN and WAN segments; and

Figure 3 is a flow chart detailing the different steps in a method of the invention.

#### Detailed Description of the Preferred Embodiment

Referring to Figure 1, a network 10 is illustrated. As can be seen, the network 10 is composed of routers R1-R19 and non-router objects N1-N27. The non-router objects N1-N27 can be switches, hubs, network nodes, or any other device connected to a network.

For clarity, it should be noted that each object, whether it be a router or not, may have multiple ports. Figure 1 shows the port number for each object next to its link. For example, non-router object N5 has 4 ports: N5(1) (meaning object N5 port 1) connecting to N4(3), N5(2) connecting to N6(1), N5(3) connecting to N7(1), and N5(4) connecting to R1(1). The table (TABLE 1) below lists the connections in Figure 1 using the notation above.

TABLE 1

	<u>OBJECT</u>	<u>PORT</u>	<u>CONNECTED TO</u>
	N1	1	N2 (1)
	N2	1	N1 (1)
		2	N4 (2)
	N3	1	R19 (2)
		2	N4 (1)
	N4	1	N3 (2)
		2	N2 (2)
		3	N5 (1)
	N5	1	N4 (3)
		2	N6 (1)

1  
 2  
 3  
 4  
 5  
 6  
 7  
 8  
 9  
 10  
 11  
 12  
 13  
 14  
 15  
 16  
 17  
 18  
 19  
 20  
 21  
 22  
 23  
 24  
 25  
 26  
 27  
 28  
 29  
 30  
 31  
 32  
 33  
 34  
 35  
 36  
 37  
 38  
 39  
 40  
 41  
 42  
 43  
 44  
 45  
 46  
 47  
 48  
 49  
 50

		3	N7 (1)
		4	R1 (1)
	N6	1	N5 (2)
5	N7	1	N5 (3)
	N8	1	R3 (3)
		2	N9 (1)
	N9	1	N8 (2)
		2	N10 (2)
10	N10	1	N9 (2)
		2	R5 (1)
	N11	1	R3 (1)
		2	N12 (1)
	N12	1	N11 (2)
		2	N13 (1)
15	N13	1	N12 (2)
		2	N14 (1)
	N14	1	N13 (2)
		2	N19 (1)
		3	N20 (1)
20	N15	1	R10 (2)
		2	N16 (3)
	N16	1	N17 (1)
		2	N18 (1)
		3	N15 (2)
25	N17	1	N16 (1)
	N18	1	N16 (1)
		2	R13 (1)
	N19	1	N14 (2)
		2	R14 (2)
30	N20	1	N14 (3)
		2	R14 (3)
	N21	1	R16 (2)
		2	N22 (1)
	N22	1	N21 (2)
35		2	N26 (1)
	N23	1	N24 (1)
		2	N21 (3)
		3	N25 (1)
40	N24	1	N23 (1)
		2	N17 (2)
	N25	1	N23 (3)
		2	N27 (1)
	N26	1	N22 (2)
	N27	1	N25 (2)
45	R1	1	N5 (4)
		2	R4 (1)
		3	R2 (1)
	R2	1	R1 (3)
		2	R3 (2)

	R3	1	N11(1)
		2	R2(2)
		3	N8(1)
5	R4	1	R1(2)
		2	R9(1)
	R5	1	N10(2)
		2	R6(1)
		3	R7(1)
10	R6	1	R5(2)
		2	R7(2)
	R7	1	R5(3)
		2	R6(2)
		3	R8(1)
15	R8	1	R7(3)
		2	R7(1)
	R9	1	R4(2)
		2	R10(1)
		3	R11(1)
20	R10	1	R2(1)
		2	N15(1)
	R11	1	R9(3)
		2	R12(1)
	R12	1	R11(2)
		2	R15(1)
25	R13	1	N18(2)
		2	R18(1)
	R14	1	R15(2)
		2	N19(2)
		3	N20(2)
30	R15	1	R12(2)
		2	R14(2)
		3	R16(1)
	R16	1	R15(3)
		2	N21(1)
35	R17	1	R8(2)
		2	N24(2)
	R18	1	R13(2)
		2	R19(2)
40	R19	1	R18(2)
		2	N3(1)

To determine the route a packet takes in  
 travelling from one point in the network 10 to another  
 point in the same network, a number of constraints have  
 45 to be placed on the route to be found, otherwise the  
 process may become, if not untenable, then impractical.



These are:

- a) a path cannot pass through a broken device or interface;
- b) a path cannot pass through an interface which, although up, is carrying no traffic;
- c) a path cannot loop back on itself.

Furthermore, it should be assumed that the topology or the interconnections between the different elements of the network, is known. This not only greatly simplifies the process but actually allows the process to be carried out. If the topology is not known, the methods described by Dawes et al in US Patent 2,926,462 and US Patent 5,933,416 as noted above can be used to find the topology. For the purpose of this document, the topology of the network 10 is as shown in Figure 1.

With these constraints in mind, the first step in the process is to decompose the network 10 into router objects and non-router network objects. It should be clear from Figure 1 and from the above that objects R1-R19 are routers while objects N1-N27 are non-router objects. Based on this, the network 10 can then be divided into WAN segments and LAN segments. Since LAN segments are connected non-router objects bound by router objects, network 10 has five LAN segments 20, 30, 40, 50, 60. Also, since WAN segments are interconnected router objects bounded by LAN segments, network 10 has three WAN segments 70, 80, 90.

To assist in the understanding of the above, Figure 2 illustrates the interconnections between the LAN and WAN segments. Reference to Figures 1 and 2 should make the discussion clear. LAN segment LAN1 (20) is composed of non-router objects N1, N2, N3, N4, N5, N6

and N7. LAN segment LAN2 (30) is composed of non-router objects N8, N9, and N10. LAN segment LAN3 (40) is composed of non-router objects N21, N22, N23, N24, N25, N26, and N27. LAN segment LAN4 (50) is composed of non-router objects N11, N12, N13, N14, N19 and N20. LAN segment LAN5 (60) is composed of non-router objects N15, N16, N17 and N18.

For the WAN segments, WAN segment WAN1 (70) is composed of router objects R1, R2, R3, R4, R9, R10, R11, R12, R14, R15 and R16. WAN segment WAN2 (80) is composed of router objects R5, R6, R7, R8 and R17. WAN segment WAN3 (90) is composed of router objects R13, R18 and R19.

Also as can be seen from Figure 2, the router object connecting a LAN segment to a WAN segment is noted next to the link. Thus, as an example, router object R5 connects WAN segment WAN2 (80) to LAN segment LAN2 (30) while router object R17 connects LAN segment LAN3 (40) to WAN segment WAN2 (80).

Assuming non-router object N1 is the source of a packet and router object N27 is the destination, the path must therefore be determined for each LAN or WAN segment the packet traverses. To find the sequence of routers the packet would traverse, non-router object N1 could use the well known and widely available traceroute function. This function, essentially a small utility program run by a node, records the sequence of routers passed through from the computer invoking the utility to a given destination. Thus, if non-router object N1 invokes the traceroute utility, the sequence of routers could be:

R1-R4-R9-R11-R12-R15-R16.

If this was the sequence returned, and based on the

known topology of the network 10, it can be seen that only WAN segment WAN1 (70) is traversed. However, if the sequence returned were as follows:

R1-R2-R3-R5-R7-R8-R17

5 then, again using the knowledge of the topology, the route traverses not only WAN segment WAN1 (70) but also WAN segment WAN2 (80). This is because routers R5, R7, R8 and R17 are in WAN segment WAN2 while the other routers are in WAN segment WAN1. Also, since WAN  
10 segment WAN2 is traversed, it is clear that the path through LAN segment LAN2 must also be determined in addition to the routing through LAN segments LAN1 (the source LAN segment) and LAN3 (the destination LAN segment)

15 If, for the purposes of this example, the traceroute utility returned the first sequence of the routers, the sequence which only traverses WAN segment WAN1, we therefore know the route through the WAN segment. To determine the route through LAN segments  
20 LAN1 (20) and LAN3 (40), each non-router element in those LAN segments would have to be queried. Each non-router network object, whether it is a switch or hub, keeps a record (in a table) of the source MAC (Media Access Control) address of the packets which transit  
25 through it. Thus, by examining these tables, it can be determined which network object receives packets from which source network object.

As an example, the table below (Table 2) shows some of the non-router objects of LAN segment LAN1  
30 (20) and the source MAC addresses of packets these objects have received.

TABLE 2

	<u>LAN1 Object and Port</u>	<u>Source MAC Address and Packets</u>
5	N1 (1)	N2, N3, N5, N6, N7, N4 R1, R19
	N2 (1)	N1
	N2 (2)	N4, N5, N7, R1, R19
	N3 (1)	R19
10	N3 (2)	N1, N2, R1, N4, N5
	N4 (1)	N3, R19
	N4 (2)	N1, N2
	N4 (3)	R1, N5, N6, N7
	N5 (1)	R19, N3, N4, N1, N2
15	N5 (2)	N6
	N5 (3)	N7
	N5 (4)	R1

From the table above, non-router object N1  
can be "seen" by non-router objects N2, N3, N4, N5, N6,  
and N7. This is because each of these objects can  
receive packets originating from N1. (E.g. N2 can  
receive it through N2(1), N3 can receive it from N3(2),  
etc). The objects traversed by a packet from N1  
(source) to R1 (interim destination) are the objects  
which can receive packets from N1, N3, N6 and N7 while  
capable of receiving packets from N1, is, from the  
topology of the LAN segment, clearly not on the route  
from N1 to R1. Since it is known that N2 is the only  
link to N1, then N2 must be on the path. Also, since it  
is known that N4 is the only link to N2, then N4 must be  
on the path as well.

Because N3 is not connected to R1 and since  
there is no link from N3 to N5 without going through N4,  
then N3 is not on the path from N1 to R1. We can see  
that N5 is the only link to R1 - N5 must therefore be on  
the path from N1 to R1.

Thus, from the topology and Table 2, a

packet must travel from N1 to R1 (since R1 is the first router encountered travelling from N1 to N27 as determined from the sequence of routers using traceroute above) via the following objects and ports:

5

N1(1)->N2(1)->N2(2)->N4(2)->N4(3)->N5(1)->N5(4)->R1(1).

The analysis therefore looks for a route from within the LAN segment going to a destination (albeit interim) that is external to the LAN segment.

10

Once the packet has entered router R1, it has effectively left LAN1 and is in WAN1.

At this point, it is already known what sequence of routers that packets traverses through WAN1. What is therefore needed is the path from WAN1 to LAN segment LAN3 (40) and the path within LAN3. Again, each object in LAN3 would have to be queried for its MAC source address table entries. If we take these as follows:

15

20

TABLE 3

	<u>LAN3 Object and Port</u>	<u>Source MAC Address</u>
25	N21(1)	R16
	N21(2)	N22, N26
	N21(3)	N23, N24, N25, R17, N27
	N22(1)	N21, R16
	N22(2)	N26, N27
30	N23(1)	N24, R17
	N23(2)	N21, R16
	N23(3)	N25, N27
35	N24(1)	N23, N25, N21, R16, N27, N22, N26
	N24(2)	R17
	N25(1)	N23, N21, R16, N24, R17
	N25(2)	N27
	N26(1)	N22, N21, R16

N27(1)

N16, N21, N23, N25, R17,  
N24, N22, N26

5       For this LAN segment, the analysis is the  
converse of that for LAN1. While in LAN1 the route was  
from within the LAN segment to a point external to the  
LAN segment, for the destination LAN segment to a point  
within the LAN segment. Thus, router R16 must be  
treated as the source MAC address and objects which can  
10       "see" R16 are of interest. From TABLE 3, these objects  
are N21, N22, N23, N24, N25, N26, and N27. Since N21 is  
the only route to the router, N21 must be on the path.  
From the topology, N25 is the only link to N27 so N25  
must be on the route to N27. Since N23 connects (again  
15       from the topology) N21 and N25 (both of which are on the  
route) then N23 must be on the route as well. Thus, the  
sequence of non-router objects traversed when travelling  
from R16 to N27 is as follows:

20       R16(2)->N21(1)->N21(3)->N23(2)->N25(1)->N25(2)->N27(1).

25       Since we now have the route through LAN1,  
WAN1, and LAN3, these paths can be put together to  
arrive at the full path from N1 to N27:

LAN1: N1->N2->N4->N5 → WAN1

WAN1: R1->R4->R9->R11->R12->R15->R16 → LAN3

LAN3: N21->N23->N25->N27

30       It should be noted that, once a packet leaves  
a WAN segment and enters a LAN segment, that packet's  
source MAC address becomes the exit port of the last  
router it went through. Thus, a packet from N1 to N10  
will have a source MAC address of N1 as it travels

through LAN1. However, once that packet enters LAN2, its source MAC address becomes R3, this being the last router that it exited.

5 It should be also be noted that path ambiguities, especially in LAN segments, can sometimes be resolved by logic. For example, if a packet is leaving object N12 (source) to arrive at router R14 but none of the ports of object N14 report seeing packets from object N12, it should be clear that object N14 is  
10 on the path. This is because N14 *must* be on the path to pass the packet through to either N19 or N20 and subsequently to R14.

Determination of the path through LAN segments therefore requires repeated readings of the  
15 source address capture information from devices/objects in that LAN segment. This can be accomplished using the Simple Network Management Protocol (SMNP).

While the above example found the path from N1 to N27, the return path, with N27 as the source and  
20 N1 as the destination, may not be the same. Such a path may traverse the network from LAN3 to WAN2 to WAN1 and finally to LAN1. Determining this path would involve finding the path through the different LAN segments (LAN3, LAN2, and LAN1) and the different WAN segments  
25 (WAN2 and WAN1).

While the method outlined above can determine the path from a specific source to a specific destination, it would be difficult to determine the path from an arbitrary source to an arbitrary destination,  
30 especially if a control computer were not the source. If, again with reference to Figure 1, N1 was the control computer and the path from N17 to N24 were required, it would be quite difficult for N1 to find this path.

However, if specific objects were designated as beacon objects, these beacon objects could find the data required and report such data back to the control computer. A beacon object is essentially a network object, usually a non-router object, which traces paths through the network and reports these paths to the control computer. Designating and using a beacon object can be as simple as having the control computer send instructions to a network object A to perform a traceroute from itself, object A, to another network object B. The network object A will then perform this duty and, once the results of the traceroute function have been received, sends this result to the control computer. As an example, if N16 were designated as a beacon object, it could determine a path from itself (N16) to the destination (N24). Since N17 is only one link away from the beacon, the path from N17 would simply be the path from the beacon (N16) to the destination (N24) plus the hop from N17. Similarly, if one wished to find the route from R5 to R17 (the path being ambiguous at R5), N10 could be designated as a beacon. By executing the traceroute function from N10 to R17, this ambiguity may be resolved. This is because a packet travelling from N10 to R17 must transit through R5 and either R6 or R7.

For optimal placement of beacon objects, the topology of the network and the location of the source or destination objects must be taken into account. If a LAN segment interconnected two segments through which the path passed, a beacon placed in that interconnecting LAN segment would be very advantageous. Thus, from Figure 2, if the source was in LAN4 (such as N19) and the destination was in LAN3 (such as N25) with R16 not



carrying any traffic or is down, the only route would be LAN4->WAN1->LAN2->WAN2->LAN3. A beacon placed in LAN2 could prove very helpful in finding this path.

Alternatively, if a LAN segment contained at least one source or destination, a beacon in that LAN segment would also prove advantageous. For example, if the source was N13 and the destination was N2 with router R1 down or inoperative, beacons could be placed at N14, N16, and N4. N14 would prove advantageous as it is in the same LAN segment as the source. N16 is in a LAN segment connecting two WAN segments (WAN1 and WAN3), while N4 is in the same LAN segment as the destination.

Once the routing from a source to a destination has been determined, the performance of that route can be measured. Because the specific objects traversed in travelling from a source to a destination is known, the overall performance of that route is merely a function of the individual performance of each of these objects.

More specifically, using known methods, such as those discussed in the Canadian application No. 2,196,133 and in US application serial no. 09/599,963, the disclosure of which are incorporated herein by reference, the end to end performance of a path can be easily found. One possible performance measure for a path is the end to end transmission fraction over a specific path. This measures what fraction of packets are actually transmitted from a source to a destination. If we define  $D(i)$  as the drop rate on a device (if  $D(A)=0.12$ , this means 12% of packets are lost while transmitting through device A) and  $T$  as the end to end transmission fraction over a path from the object 1-N, then

$$T = \prod_{i=1..N} (1 - D(i))$$

Another performance measurement which may be used is that of end to end delay. By determining the delay through each network element, through known methods, and aggregating such delay measurements for a specific path, the end to end delay for that path can be found.

A further performance measurement is that of end to end availability. By finding the break state or availability of each network element, again from known methods, and then applying the above method for finding a specific path to these, the end to end availability of the path can be found.

From the above end to end performance measurements and from the performance measurements of the individual network element, bottlenecks within the network can be found. If one knows the end to end performance of a path and the performance of the individual network elements, bottlenecks can be pinpointed -- whichever network element has the highest performance measurement or the most throughput is most likely the bottleneck.

These and other performance measurements can therefore be found more easily using the path determining method above.

To clarify the method outlined above, Figure 3 illustrates a flowchart detailing the steps executed.

Beginning at the BEGIN box 100, box 110 notes that the objects in the network must be determined if they are router objects or non-router objects. In box

120, the network is decomposed in LAN and WAN segments. Box 130 notes that all routers must be grouped into WAN segments. Each WAN segment must be bounded by or regenerated from other WAN segments by at least one non-  
5 router object. Once the WAN segments have been grouped, box 140 notes that the sequence of routers from the source to the destination must be found. As noted above, the well known traceroute function can be used for this. Well placed beacon objects in the network can  
10 be used for the traceroute step if required. The step in box 150 is optional as evidenced by the dashed box around it. Step 150 would be most useful if the path traversed multiple WAN segments, such as if the path led through WAN1 and WAN2 in Figures 1 and 2. If, however,  
15 the path only led through a single WAN segment, beacons may not be required.

Once the path is determined through the WAN segments, any intervening LAN segments interconnecting the WAN segments must be resolved. (E.g. if the path  
20 led through WAN1, WAN 2, and LAN2 in Figure 2, the path through LAN2 would have to be found). (See box 160).

It should be noted that the step in box 170, that of grouping the non-router segments into LAN segments, can be executed concurrently with the step in  
25 box 130. However, in the beginning of the process, the only known LAN segments are the LAN segments of the source and the destination. Thus, the two LAN segments would be the first ones grouped. Any interconnecting LAN segments between WAN segments can be grouped  
30 subsequently.

The next step is that shown in box 180 - that of reading the source address tables for the objects in the subject LAN segment. This is done to find out which

object in that LAN segment receives or "sees" the relevant source MAC address. For the LAN segment to which the source object belongs, the relevant MAC address would be the MAC address of the source object.

5 For any other LAN segment, the relevant source MAC address would be the MAC address of the router from which the packet entered the LAN segment. As an example, from Figure 1, if the router sequence was R14-R15-R16 and then N21, the relevant source MAC  
10 address for the LAN segment LAN3 would be the MAC address of router R16 and, more specifically, the MAC address of port 2 of router R16.

Once the source MAC address tables have been read, box 190 notes that path through the LAN segment  
15 must be found.

By knowing which objects "see" the relevant MAC and which objects are interconnected, the path from one point in a LAN segment to another in the same LAN segment can generally be determined. (See box 200). In  
20 case of ambiguities, logic can be used to find a reasonable path. If the ambiguity cannot be resolved, user intervention may be required.

Decision 210 determines if there are more LAN segments to be analysed. These LAN segments may have  
25 resulted from the step in box 160. If there are more LAN segments, these are immediately analysed in the loop formed by boxes 180, 190, 200, 210.

If there are no more LAN segments to be examined, this means that the path has been found. The  
30 final step (box 220) is to combine the paths found in the individual WAN and LAN segments into a coherent whole. By combining multiple segments, the path through any combination of LAN and WAN segments can be found.

The invention described above is ideally implemented with the use of a single control computer which instructs multiple beacons in the network. By using this scheme, each beacon can act as the source to determine the path to and from arbitrary points in the network. The beacons then report their findings to the control computer. From Figure 1, if the control computer was object N17 and the beacons were objects N2, N9, N13, and N21, most paths can be found. If the path from N4 to N8 were desired, N2 can act as the source. By simply removing the hop from N4 to N2, the path found is the path from N4 to N2. Similarly, if the path from N20 to N15 were desired (and assuming that a direct path existed between N13 and N14), then N13 can act as the source. The hops from N20 to N13 can be removed from the resulting path to find the desired path from N20 to N15.

A person understanding the above-described invention may now conceive of alternative designs, using the principles described herein. All such designs which fall within the scope of the claims appended hereto are considered to be part of the present invention.

We Claim

1. A method of determining a routing for packets in a network, said method comprising:

a) dividing said network into WAN (Wide Area Network) segments and LAN (Local Area Network) segments;

5 b) determining a routing for packets through each segment;

c) combining routing results obtained in step b) to obtain a total routing through the network.

2. A method as in claim 1 wherein step a) includes determining which network objects are routers and which network objects are non-routers.

3. A method as in claim 2 further including partitioning non-router network objects into discrete LAN segments, each LAN segment being a collection of connected non-router network objects separated from other non-router network objects by at least one router.

4. A method as in claim 2 including partitioning routers into WAN segments, each WAN segment being a collection of connected routers separated from other routers by at least one non-router network object.

5. A method as in claim 4 wherein step b includes determining for each WAN segment a sequence of routers a packet passes through from a source router to a destination router in the WAN segment.

6. A method as in claim 3 wherein step b

includes determining for each segment which non-router network objects a packet passes through from a source non-router network object to a destination non-router network object in the LAN segment.

7. A method as in claim 1 wherein step b) is executed from a plurality of beacons located at different points in the network.

8. A method as in claim 6 wherein step b includes reading a table of source addresses at each non-router network object in each LAN segment, said table containing source addresses of packets which transit through said non-router network object.

9. A method as in claim 3 wherein step b is accomplished using a previously determined topology of the network.

10. A method as in claim 5 wherein the sequence of routers a packet passes through is determined from a plurality of beacons located at different points in the WAN segment.

11. A method of determining a packet's routing through a LAN segment composed of multiple network objects, said method comprising:

a) determining a network address of a source network object;

b) determining a network address of a destination network object;

c) determining which network objects receive packets from the source network object;

d) determining connections between network objects using the topology of the LAN segment; and  
e) determining which network objects are in a route from the source network object to the destination network objects based on data obtained in steps c) and d) .

12. A method of determining the performance of a route in a network, the method comprising:

a) determining a source network object;  
b) determining a destination network object;  
c) determining a route through the network from the source network object to the destination network object;

d) measuring the network performance of each network object on the route; and

e) aggregating the network performances obtained in step d) to obtain a total network performance for the route.

13. A method as in claim 12 wherein said network performance is that of a packet's delay through said network element and said total network performance for the route is the total end to end delay for a packet traversing said route.

14. A method as in claim 12 wherein said network performance is that of a network element's drop rate of packets and said total network performance is the end to end transmission fraction over a path.

15. A method as in claim 14 wherein said end to end transmission fraction over a path is determined



according to

$$T = \prod_{i=1 \dots N} (1 - D(i))$$

where

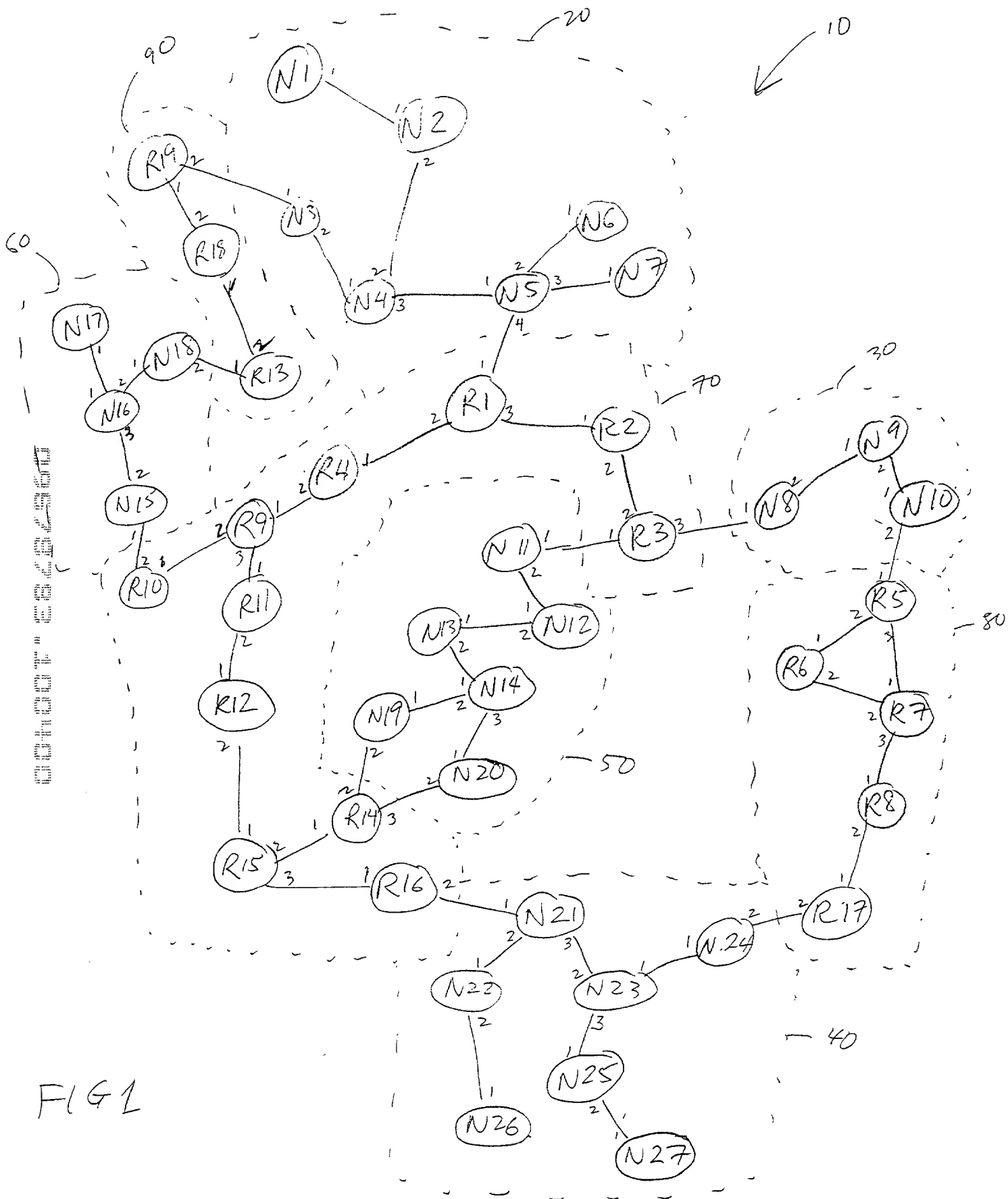
5           T = end to end transmission fraction over a  
            path from object 1-N

D(i) = drop rate of device i.

16. A method as in claim 12 wherein said  
network performance is a network element's throughput  
and said total network performance is a determination of  
bottlenecks in said path.

## ABSTRACT

A method of determining a routing for packets in a network, the method comprising a) dividing the network into WAN (Wide Area Network) segments and LAN (Local Area Network) segments; b) determining a routing for packets through each segment; combining routing results obtained in step b) to obtain a total routing through the network.



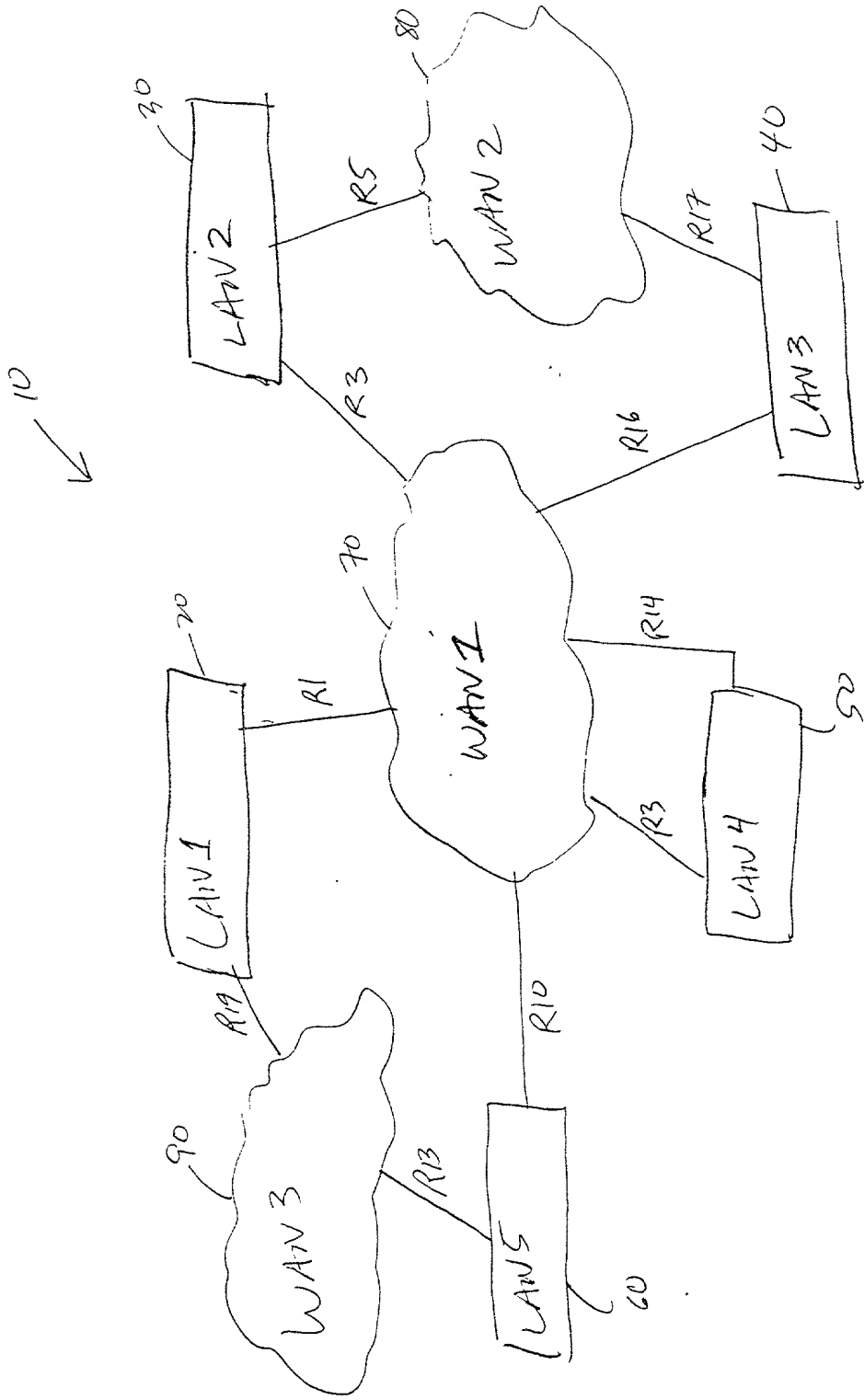


FIG 2

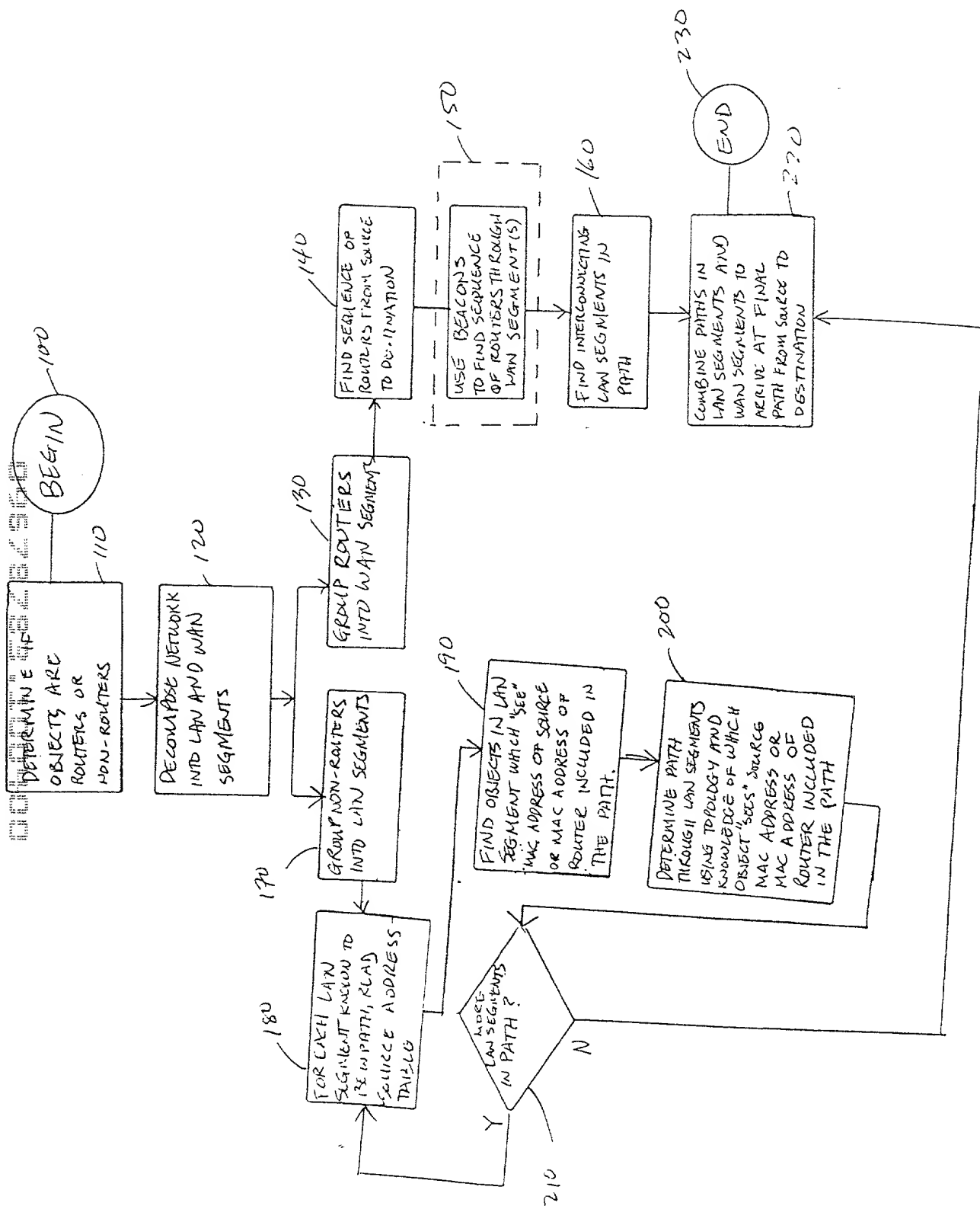


FIG 3

Please type a plus sign (+) inside this box → ☐

PTO/SB/01 (12-97)  
Approved for use through 9/30/00. OMB 0651-0032  
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

**DECLARATION FOR UTILITY OR  
DESIGN  
PATENT APPLICATION  
(37 CFR 1.63)**

☒ Declaration  
Submitted  
with Initial  
Filing  
OR  
☐ Declaration  
Submitted after Initial  
Filing (surcharge  
(37 CFR 1.16 (e))  
required)

Attorney Docket Number	551P08US-1
First Named Inventor	Dawes, Nicholas W.
COMPLETE IF KNOWN	
Application Number	/
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD OF DETERMINING THE ROUTE OF PACKETS THROUGH A  
NETWORK OF COMMUNICATING OBJECTS

the specification of which (Title of the Invention)

☒ is attached hereto  
OR

☐ was filed on (MM/DD/YYYY) as United States Application Number or PCT International

Application Number and was amended on (MM/DD/YYYY) (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
				YES	NO
2,304,542	Canada	04/10/2000	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	<input type="checkbox"/> Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

[Page 1 of 2]

Burden Hour Statement: This form is estimated to take 0.4 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

Please type a plus sign (+) inside this box → +

PTO/SB/01 (12-97)  
Approved for use through 9/30/00. OMB 0651-0032  
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

## DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

☐ Customer Number  → Place Customer Number Bar Code Label here  
OR  
☒ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
R.A. Wilkes	28170		
H.C. Baker	19333		
R.G. Hendry	22927		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to: ☐ Customer Number  OR ☒ Correspondence address below

Name	Pascal & Associates				
Address	P.O. Box 11121				
Address	Station H				
City	Nepean	State	Ontario	ZIP	K2H 7T8
Country	Canada	Telephone	(613) 820-1366	Fax	(613) 820-1553

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor:		<input type="checkbox"/> A petition has been filed for this unsigned inventor	
Given Name (first and middle (if any))		Family Name or Surname	
Nicholas W.		Dawes	
Inventor's Signature			Date
Residence: City	Ottawa	State	Ontario
		Country	Canada
Post Office Address			
Post Office Address	99 Lyttleton Gardens		
City	Ottawa	State	Ontario
		ZIP	K1L 3A4
		Country	Canada

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

Please type a plus sign (+) inside this box → +

PTO/SB/02A (3-97)  
Approved for use through 9/30/98. OMB 0651-0032  
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

## DECLARATION

ADDITIONAL INVENTOR(S)  
Supplemental Sheet  
Page 1 of 1

Name of Additional Joint Inventor, if any:

☐ A petition has been filed for this unsigned inventor

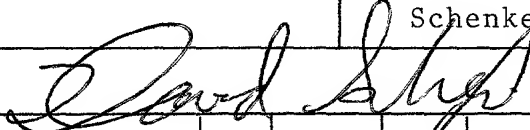
Given Name (first and middle (if any))

Family Name or Surname

David

Schenkel

Inventor's  
Signature



Date

09/29/00

Residence: City

Ottawa

State

Ontario

Country

Canada

Citizenship

CA

Post Office Address

Post Office Address

250-120D Rideau Place

City

Ottawa

State

Ontario

ZIP

K1N 9N7

Country

Canada

Name of Additional Joint Inventor, if any:

☐ A petition has been filed for this unsigned inventor

Given Name (first and middle (if any))

Family Name or Surname

Inventor's  
Signature

Date

Residence: City

State

Country

Citizenship

Post Office Address

Post Office Address

City

State

ZIP

Country

Name of Additional Joint Inventor, if any:

☐ A petition has been filed for this unsigned inventor

Given Name (first and middle (if any))

Family Name or Surname

Inventor's  
Signature

Date

Residence: City

State

Country

Citizenship

Post Office Address

Post Office Address

City

State

ZIP

Country

Burden Hour Statement: This form is estimated to take 0.4 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.